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WO-A-85/04544
FR-A- 2 243 573
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PROCEEDINGS OF EUROPEAN CONFERENCE ON OPTICAL COMMUNICATION, Session A XIII, Systems (II), 21st-24th September 1982, pages 439-441, Cannes, FR; J.P. HERRIAU et al.: "Light beam steering using a reversible photoinduced grating in B.S.O. crystals"

PROCEEDINGS OF THE INTERNATIONAL SWITCHING SYMPOSIUM, Florence, 7th-11th May 1984, session 41A, paper 5, page 1, North-Holland Publ. CO., Amsterdam, NL; P. GRAVEY et al.: "Optical switching technologies for high capacity exchanges"

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Description

This invention relates to an optical space switch which is capable of use in a centralised switching system for an optical network. A centralised switching system is the simplest active network which is compatible with optical and electronic multiplexing, offers the maximum network size, range, and flexibility and is also compatible with the existing wire-networks.

United States patent No. 3,985,975 described an optical space switch comprising a plurality of inputs for optical signals, a spatial light modulator for receiving optical signals and controllable to impose a selected spatial phase modulation thereon, a multiplexed phase hologram disposed to receive optical signals from the modulator and containing a plurality of individual holograms to diffract light in a manner determined by the imposed spatial phase modulation, and collection means including a plurality of output receptors for collecting light diffracted by the holograms, each hologram diffracting light to a selected receptor in dependence upon the spatial modulation imposed by the spatial phase modulator.

Although it has a plurality of inputs, the optical signals from these all illuminate a single spatial phase modulator and a single multiplexed hologram, so that only one optical signal can be routed to an output receptor at any given time.

Accordingly, in the present invention, the switch includes a plurality of spatial light modulators each disposed to receive optical signals from a respective one of the inputs and a plurality of multiplexed phase volume holograms each disposed to receive optical signals from a respective modulator, and the plurality of output receptors is common to all the multiplexed phase volume holograms whereby optical signals from a plurality of inputs may be simultaneously directed to desired output receptors.

Preferably the number of holograms in each multiplexed phase volume hologram is equal to the number of receptors. This arrangement provides total flexibility and enables each and every input to be coupled to each and every output. However, in some circumstances it is desirable to be able to arrange for (for example) two outputs to receive the same signal. In this case, there may be greater numbers of holograms in each multiple of phase volume hologram than there are outputs.

The inputs may be provided by the ends of a plurality of optical fibre waveguides, or, alternatively, the inputs may be formed by optical devices the outputs of which are modulated by the input signals. Thus, the optical inputs may all be taken from a single optical source which is split and each split component modulated in accordance with an input signal, or alternatively, the devices may be formed by a number of independent optical sources each of which is modulated by an input signal. The receptors may be formed by the ends of an array of optical waveguides leading away from the optical space switch and, in this case they are preferably formed by an array of multimode optical fibres. Alternatively, the receptors may be formed by an array of photo detectors or other active devices such as self electrooptic effect devices which detect, amplify, or regenerate the light received. Photo detectors may form part of an optical regenerator which, in turn, generates an output in the form of an optical signal. The inputs may be arranged in a linear array and, in this case the receptors may also be arranged in a linear array extending in a direction perpendicular to that of the linear input array. Alternatively, the input and/or outputs may have the form of two dimensional matrix arrays.

The spatial light modulator may be formed buy a material the refractive index of which may be varied by the application of an electrical or optical signal or it may be formed from a material the physical dimensions of which can be changed selectively by the application of an electrical signal. In either case the change of phase across the wavefront of light passing the spatial light modulator can be varied by the selective application of an electrical or optical control signal to the spatial light modulator. Examples of spatial light modulators are acousto-optic transducers and liquid crystals.

The multiplexed phase volume holograms may be reflection or transmission holograms or may be mixtures of both reflection and transmission holograms. The holograms may also be of the Fourier transform phase volume hologram type.

To create the multiplexed phase volume holograms an unexposed holographic recording medium is placed in position downstream of the inputs (which during creation of the holograms act as reference sources) and the spatial light modulators. An object array corresponding to the collectors is located on the same side of the holographic recording medium as the inputs and spatial light modulators and when creating a transmission hologram in a laterally offset position. Light from a coherent source, typically a laser, is applied via one of the inputs and the spatial light modulator to form a reference beam which impinges upon a section of the holographic recording medium which receives light from that input. Another beam taken from the same coherent light source and passing through an equivalent path length is applied via one of the objects, typically the output end of a single mode optical fibre waveguide which then is distributed over the same section of the surface of the holographic recording medium. Light from the

same source but which has passed through these two different paths then interferes in the volume of the holographic recording medium to expose a particular pattern in that section of the holographic recording medium. Then, light is emitted from a different object and a different control signal is applied to the spatial light modulator. A further exposure of that section of the holographic recording medium is repeated until a pattern is exposed for each of the object sources, each one having a different control signal applied to the spatial light modulator so that the reference beam used to create the hologram has a different phase front. Thus, each reference and point source are stored in association with one another.

The next section of the holographic recording medium which receives light from the next input is then exposed by applying the reference beam to the next input and making another series of exposures with each and every object and with different control signals applied to the spatial light modulator. This process is repeated with a reference beam being applied to each and every input until the entire holographic recording medium has been exposed. The recording medium is then processed to produce the multiplexed phase volume holograms.

Thus, with this system when light from a particular input passes via the spatial light modulator to its multiplexed phase volume hologram since the light from the input forms a reconstruction beam following the path of the reference beam a virtual image is formed at the location of the object and the collection means focuses light diffracted by the hologram onto the corresponding receptor in dependence upon the control signal that is applied to the spatial light modulator. The light diffracted by the multiplexed phase volume hologram consists not only of the associated virtual image or object wave but diffracted waves from all of the other holograms in that multiplexed phase volume hologram. The collection means focuses the light diffracted by the hologram corresponding to the required virtual image on to the receptor while the light diffracted by other holograms is widely dispersed over the output plane. In principle, the light dispersed from the other holograms can be made orthogonal at the point of focus on the output plane by using an orthogonal function in the spatial encoding process of the reference waves e.g. Walsh or Hadamard functions. Since the diffraction efficiency of the individual holograms falls as the number of holograms in each multiplexed phase volume hologram is increased and the power of the light incident upon the hologram is shared between the multiple diffractions the switch insertion loss grows rapidly with increasing numbers of outputs. This loss can be minimised in a phase volume hologram by maximising the angular separation between the object point sources, and hence between the outputs so that the Bragg extinction angle eliminates most of the undesired interference terms. In practice, it is possible to superimpose more than one thousand holograms of coded individual point sources on a single multiplexed hologram and it is believed that two or three orders greater than this may be possible.

A particular example of an optical switch in accordance with this invention will now be described with reference to the accompanying drawing which is a diagrammatic perspective view.

The optical switch comprises a number of inputs formed by a linear array of single mode optical fibres 1, a spherical and cylindrical lens combination 2, a spatial light modulator 3, a number of multiplexed phase volume holograms 4, and collection means comprising a lens combination 5 and a linear array of multimode optical fibres 6 forming a number of output receptors. The spherical and cylindrical lens combination 2 spreads light leaving the end of the input fibres 1 in the vertical direction as shown in the drawing to spread it over a vertical column of the spatial light modulator 3 and a similar vertical column of the hologram 4. The hologram 4 is formed by a number of vertical sections arranged side-by-side. The sections are associated with the individual input fibres 1 and light from the first input fibre is only incident upon the first section. The spatial light modulator 3 equally includes a number of vertical sections with each section only receiving light from its corresponding input fibre. The spatial light modulator 3 is formed by an acousto-optic modulator. A separate control signal is applied to each of these sections to vary the phase change that occurs on passage of light through the section of the spatial light modulator 3. The multiplexed phase volume holograms that are recorded in each section of the hologram 4 diffract the light passing through the hologram 4 in such a way that it is focused by the lens 5 onto one of the output fibres 6. Which of the output fibres 6 the light is focused upon is determined by the phase front that is imposed on the leight as it passed through the spatial light modulator 3. Thus, by varying the control signal applied to the individual sections of the spatial light modulator 3 the input signal appearing on each input fibre 1 is coupled to a particular individual output fibre 6.

To create the holograms a holographic recording medium 4' is located where the hologram 4 is located and a number of object sources formed by the ends of a linear array of single mode optical fibres 7 are provided. The object sources 7 are complementary to output fibre 6 and may include a similar optical system 8 but the object fibres 7 are located on the same side of the holographic re-

cording medium 4' as the input fibres 1. To record the holograms on the medium 4' a single coherent optical source (not shown) typically formed by a laser is applied via a beam splitter to one of the input fibres 1 and also to a selected object fibre 7. When the coherent source is applied to the first input fibre 1 a first strip of the medium 4' is uncovered, a first control signal is applied to the spatial light modulator 3, and the coherent light is also applied to one of the object fibres 7. Thus, coherent light from the coherent light source is fed firstly via one of the fibres 1, the lens system 2 and the spatial light modulator 3 and, independently, via one of the object fibres 7 and the lens system 8 and both of these beams interfere with one another in the first section of the holographic recording medium 4'. This exposes a first pattern in the first section of the medium 4'. Then, a second control signal is applied to the first section of the spatial light modulator 3 and light from the coherent light source is then fed to the second object fibre 7 as well as the first input fibre 1. Another exposure is made of the first section of the holographic recording medium 4' and this process is repeated until a pattern is recorded in the first section of the holographic recording medium 4' for each one of the object fibres 7, each time a different control signal being applied to the first section of the spatial light modulator 3. Then, the coherent light source is applied to the second one of the input fibres 1, a first control signal is applied to the second section of the spatial light modulator 3 and the first section of the holographic recording medium 4' is covered up and a second section exposed. The process is repeated until all of the patterns are exposed on the second section of the holographic recording medium 4'. This process is continued to expose as many sections across the holographic recording medium 4' as there are input fibres 1. The holographic recording medium 4' is then processed in the conventional way to produce the required multiplexed phase volume holograms 4.

In preparing the holographic recording medium 4' the light from the input fibres 1 and which has passed through the spatial light modulator 3 forms the reference beam and the light from the fibres 7 forms the object. Thus, when the developed hologram 4 is illuminated by light from a source of substantially the same wavelength as the coherent light used to prepare the hologram 4, the light diffracted by the hologram 4 appears to have come from a virtual image located at the position of the object fibre 7. This light is thus focused by the optical system 5 on to one of the output fibres 6. Since a different control signal was applied to the spatial light modulator 3 when different object fibres 7 were illuminated and used as objects during the construction of the hologram,, by applying particular control signals to the spatial light modulator 3 when input signals are fed from the input fibres 1 these are switched by the hologram 4 to particular of the output fibre 6 corresponding to the object fibre 7.

Claims

1. An optical space switch comprising a plurality of inputs (1) for optical signals, a spatial light modulator (3) for receiving optical signals and controllable to impose a selected spatial phase modulation thereon, a multiplexed phase hologram (4) disposed to receive optical signals from the modulator and containing a plurality of individual holograms to diffract light in a manner determined by the imposed spatial phase modulation, and collection means (6) including a plurality of output receptors for collecting light diffracted by the holograms, each hologram diffracting light to a selected receptor in dependence upon the spatial modulation imposed by the spatial phase modulator,
   characterised in that
   the switch includes a plurality (3) of spatial light modulators each disposed to receive optical signals from a respective one of the inputs (1) and a plurality (4) of multiplexed phase volume holograms each disposed to receive optical signals from a respective modulator, and in that the plurality (6) of output receptors is common to all the multiplexed phase volume holograms whereby optical signals from a plurality of inputs may be simultaneously directed to desired output receptors.

2. An optical space switch according to Claim 1, in which the number of holograms in each multiplexed phase volume hologram is equal to the number of receptors whereby any of the signals may be directed to any of the receptors.

3. An optical space switch according to claims 1 or 2, in which the inputs are provided by the ends of a plurality (1) of optical fibre waveguides.

4. An optical space switch according to claim 1 or 2, in which the inputs are formed by optical devices the outputs of which are modulated by the input signals.

5. An optical space switch according to Claim 4, in which the optical inputs are all taken from a single optical source which is split and each split component modulated in accordance with

an input signal.

6. An optical space switch according to Claim 4, in which the optical devices are formed by a number of independent optical sources each of which is modulated by an input signal.

7. An optical space switch according to any one of the preceding claims, in which the receptors are formed by the ends of an array (6) of multimode optical waveguides leading away from the optical space switch.

8. An optical space switch according to any one of claims 1 to 6, in which the receptors are formed by an array of photodetectors or other active devices.

9. An optical space switch according to any one of the preceding claims, in which the inputs are arranged in a linear array (1) and the receptors are arranged in a linear array (6) extending in a direction perpendicular to that of the linear input array.

10. An optical space switch according to any one of the preceding claims, in which the spatial light modulator (3) is formed by a material the refractive index of which may be varied by the application of an electrical or optical signal.

11. An optical space switch according to any one of the preceding claims, in which the multiplexed phase volume holograms (4) are transmission holograms.

Patentansprüche

1. Räumlicher optischer Schalter mit einem Vielfach von Eingängen (1) für optische Signale, einem räumlichen Lichtmodulator (3) für den Empfang optischer Signale und steuerbar, um ihnen eine ausgewählte räumliche Phasenmodulation aufzuprägen, ein Phasenmultiplex-Hologramm (4) zum Empfang optischer Signale vom Modulator und enthaltend ein Vielfach individueller Hologramme zum Beugen von Licht in einer von der aufgeprägten räumlichen Phasenmodulation bestimmten Weise, und einem Sammler (6) mit einem Vielfach von Ausgangsrezeptoren zur Sammlung des von den Hologrammen gebeugten Lichts, wobei jedes Hologramm Licht an einen ausgewählten Rezeptor beugt in Abhängigkeit von der durch den räumlichen Phasenmodulator aufgeprägten räumlichen Modulation, dadurch gekennzeichnet, daß der Schalter ein Vielfach (3) von räumlichen Lichtmodulatoren aufweist, von denen jeder zum Empfang optischer Signale von einem zugeordneten Eingang (1) bestimmt ist, sowie ein Vielfach (4) von Phasenmultiplex-Volumenhologrammen, von denen jedes zum Empfang optischer Signale von einem zugeordneten Modulator bestimmt ist, und daß ein Vielfach (6) von Ausgangsrezeptoren allen Phasenmultiplex-Volumenhologrammen gemeinsam ist, so daß optische Signale von dem Vielfach der Eingänge gleichzeitig an die gewünschten Ausgangsrezeptoren gerichtet werden können.

2. Räumlicher optischer Schalter nach Anspruch 1, wobei die Zahl der Hologramme in jedem Phasenmultiplex-Volumenhologramm gleich der Zahl der Rezeptoren ist, wodurch jedes der Signale an jeden der Rezeptoren gerichtet werden kann.

3. Räumlicher optischer Schalter nach Ansprüchen 1 oder 2, wobei die Eingänge durch die Enden eines Vielfachs (1) von optischen Faserwellenleitern gebildet werden.

4. Räumlicher optischer Schalter nach Ansprüchen 1 oder 2, wobei die Eingänge durch optische Vorrichtungen gebildet werden, deren Ausgänge durch die Eingangssignale moduliert werden.

5. Räumlicher optischer Schalter nach Anspruch 4, wobei die optischen Eingänge alle von einer einzelnen optischen Quelle stammen, deren Strahl zerlegt wird, und jede Strahlkomponente entsprechend dem Eingangssignal moduliert wird.

6. Räumlicher optischer Schalter nach Anspruch 4, wobei die optischen Vorrichtungen durch eine Zahl von unabhängigen optischen Quellen gebildet werden, von denen jede durch ein Eingangssignal moduliert wird.

7. Räumlicher optischer Schalter nach einem der vorhergehenden Ansprüche, wobei die Rezeptoren durch die Enden einer Gruppe (6) von optischen Mehrmodus-Wellenleitern gebildet werden, die von dem räumlichen optischen Schalter wegführen.

8. Räumlicher optischer Schalter nach einem der Ansprüche 1 bis 6, wobei die Rezeptoren durch eine Gruppe von Photodetektoren oder andere aktive Vorrichtungen gebildet werden.

9. Räumlicher optischer Schalter nach einem der vorhergehenden Ansprüche, wobei die Eingän-

ge in linearer Reihe (1) angeordnet sind und die Rezeptoren in einer linearen Reihe (6) in einer Richtung senkrecht zu der der linearen Eingangsreihe angeordnet sind.

10. Räumlicher optischer Schalter nach einem der vorhergehenden Ansprüche, wobei der räumliche Lichtmodulator (3) aus einem Material besteht, dessen Brechungsindex durch Anlegen eines elektrischen oder optischen Signals geändert werden kann.

11. Räumlicher optischer Schalter nach einem der vorhergehenden Ansprüche, wobei die Phasenmultiplen-Volumenhologramme (4) Übertragungshologramme sind.

Revendications

1. Un commutateur optique spatial comprenant une série d'entrées (1) destinées à des signaux optiques, un modulateur spatial de lumière (3) destiné à recevoir des signaux optiques et réglable de manière à imposer à ceux-ci une modulation spatiale de phase choisie, un hologramne (4) à phase multiplexage disposé de manière à recevoir des signaux optiques provenant du modulateur et contenant une série d'hologrammes individuels pour diffracter la lumière d'une manière déterminée par la modulation de phase spatiale imposée, et un moyen collecteur (6) incluant une série de récepteurs de sortie pour collecter la lumière diffractée par les hologrammes, chaque hologramme diffractant la lumière vers un récepteur choisi en fonction de la modulation spatiale imposée par le modulateur de phase spatial,
caractérisé en ce que
le commutateur inclut une série (3) de modulateurs de lumière spatiaux disposés chacun de manière à recevoir des signaux optiques à partir d'une entrée respective parmi les entrées (1) et une série (4) d'hologrammes en volume à phases multiplexées disposés chacun de façon à recevoir des signaux optiques à partir d'un modulateur respectif, et en ce que la série (6) de récepteurs de sortie est commune à tous les hologrammes en volume à phases multiplexées, grâce à quoi des signaux optiques provenant d'une série d'entrées peuvent être dirigés simultanément vers des récepteurs de sortie souhaités.

2. Un commutateur optique spatial selon la revendication 1 dans lequel le nombre des hologrammes de chaque hologramme en volume à phases multiplexées est égal au nombre de récepteurs, grâce à quoi l'un quelconque des signaux peut être dirigé vers l'un quelconque des récepteurs.

3. Un commutateur optique spatial selon la revendication 1 ou 2, dans lequel les entrées sont réalisées par les extrémités d'une série (1) de guides d'ondes à fibres optiques.

4. Un commutateur optique spatial selon la revendication 1 ou 2, dans lequel les entrées sont formées par des dispositifs optiques dont les sorties sont modulées par les signaux d'entrée.

5. Un commutateur optique spatial selon la revendication 4, dans lequel les entrées optiques sont toutes prises dans une source optique unique qui est divisée, et chaque composant divisé est modulé selon un signal d'entrée.

6. Un commutateur optique spatial selon la revendication 4, dans lequel les dispositifs optiques sont formés d'une série de sources optiques indépendantes dont chacune est modulée par un signal d'entrée.

7. Un commutateur optique spatial selon l'une quelconque des revendications précédentes, dans lequel les récepteurs sont formés par les extrémités d'un réseau (6) de guides d'ondes optiques multimodes qui guident la lumière à partir du commutateur optique spatial.

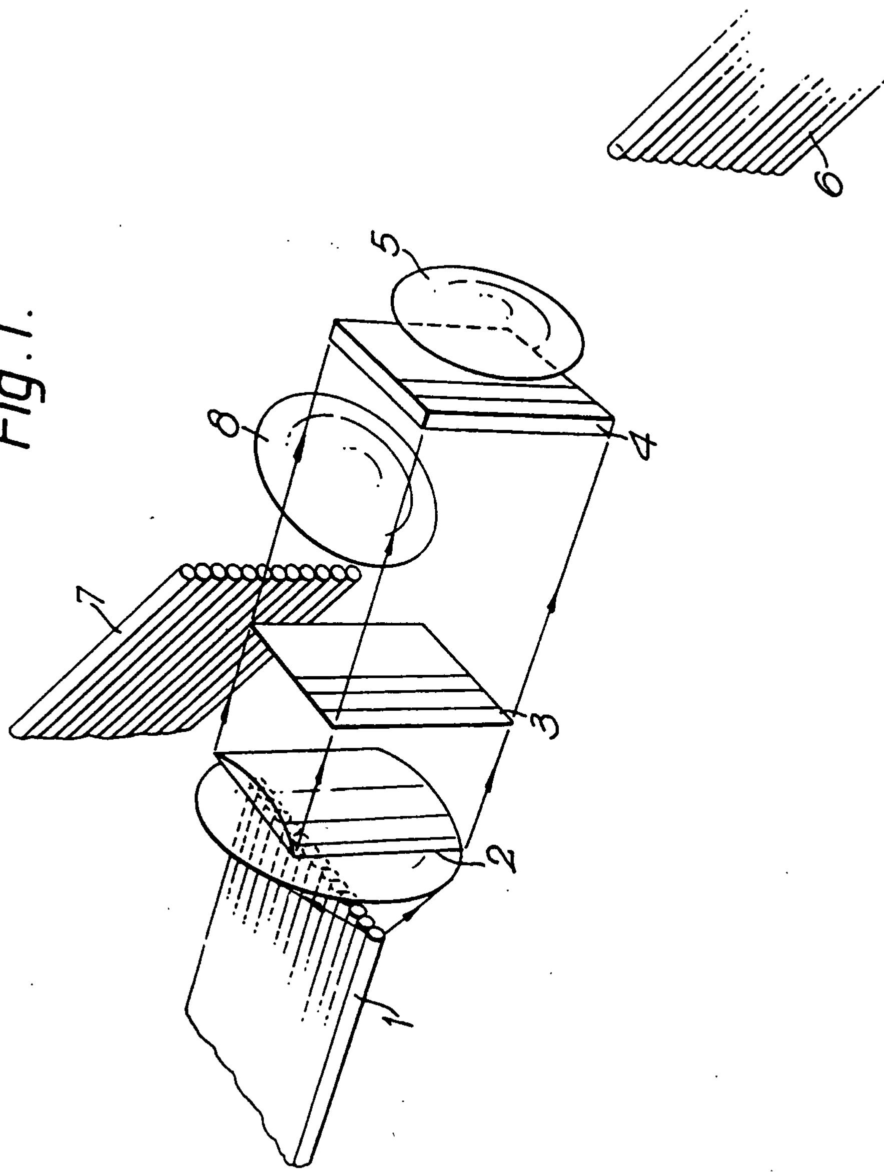
8. Un commutateur optique spatial selon l'une quelconque des revendications 1 à 6, dans lequel les récepteurs sont formés par un réseau de photodétecteurs ou d'autres dispositifs actifs.

9. Un commutateur optique spatial selon l'une quelconque des revendications précédentes, dans lequel les entrées sont agencées selon un réseau linéaire (1) et les récepteurs sont agencés selon un réseau linéaire (6) s'étendant dans une direction perpendiculaire à celle du réseau linéaire d'entrée.

10. Un commutateur optique spatial selon l'une quelconque des revendications précédentes, dans lequel le modulateur spatial de lumière (3) est formé par une matière dont on peut faire varier l'indice de réfraction par l'application d'un signal électrique ou optique.

11. Un commutateur optique spatial selon l'une quelconque des revendications précédentes, dans lequel les hologrammes en volume (4) à phases multiplexées sont des hologrammes de transmission.

Fig.1.



Optical spac switch.

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Abstract

An optical space switch is used in a centralised switching system for an optical network and connects light from one of a number of inputs (1) to a selected one of a number of outputs (6). The switch includes a number of multiplexed phase volume holograms (4), a spatial light modulator (3) for imposing a selected phase change on light passing through it, distribution means (2) for coupling light from the inputs (1) via the spatial light modulator (3) to the multiplexed phase volume holograms (4), and collection means (5) for collecting light diffracted by the multiplexed phase volume holograms (4). Each multiplexed phase volume hologram (4) diffracts light to a selected output (6) in dependence upon the phase change imposed by the spatial light modulator (3) on the light incident upon that hologram (4).